Dynamic modelling and testing of two water washes in series at Tiller plant

PCCC8-Conference

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Outline

- Introduction
- Pilot plant with the water washes.
- Types of measurements taken
- Model approach
- Results starting with pure water in the washes
- Results from introducing aerosols
- Conclusions

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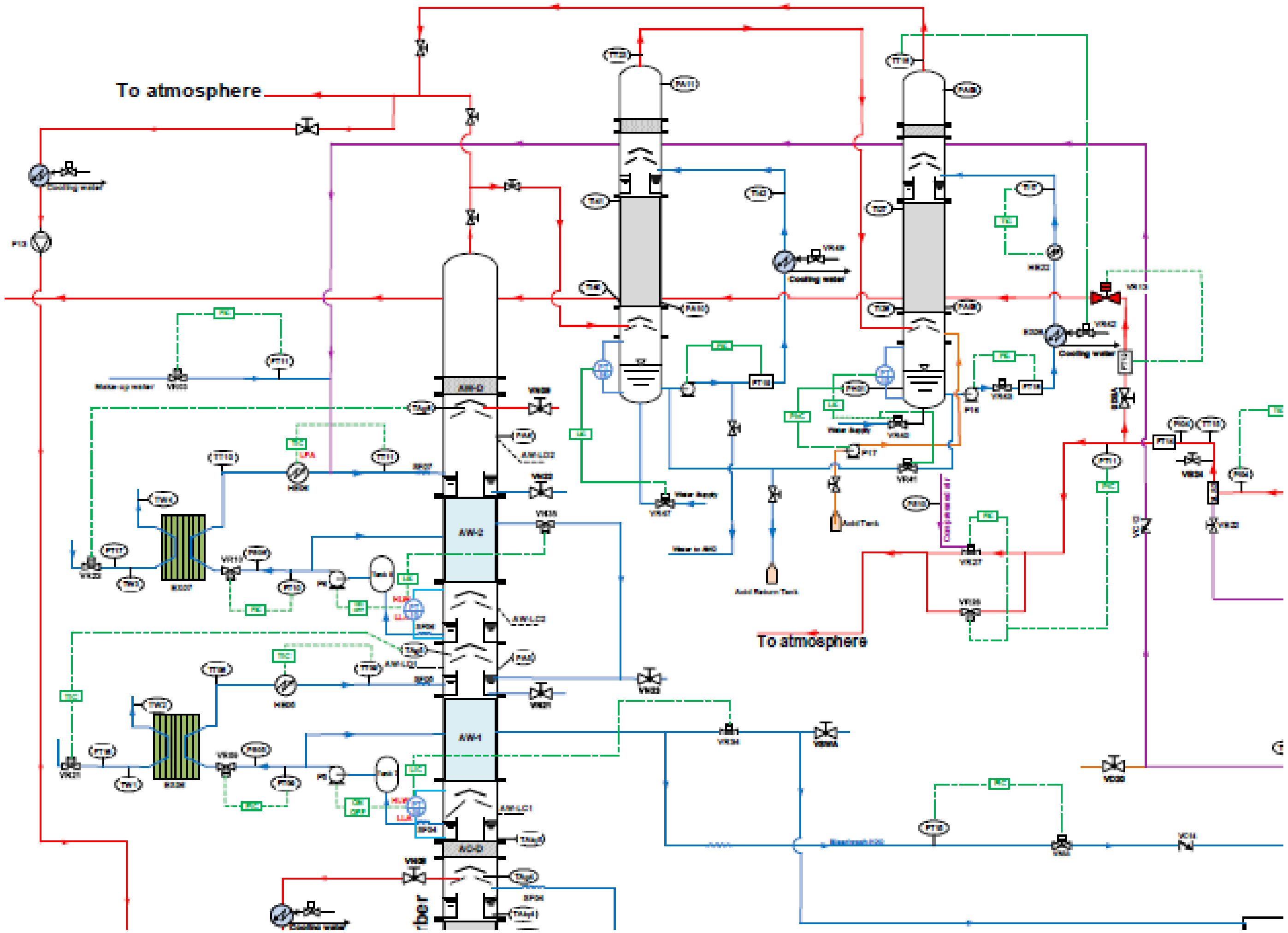
Introduction/Background

- Amine emissions to air is a crucial issue when applying amine-based absorption technology
- The emissions origin from to two different phenomena
  - Vapor-based emissions
  - Emissions from aerosols
- Use of water washing is the main technology to handle vapor-based emissions
- Aerosols will usually not be captured by water washes
- The objective of the present work is to
  - Make a dynamic model the two upper water wash sections at the Tiller pilot plant
  - Compare the model with measurements
  - Generally obtain better understanding of the dynamics in the WW
- The present work was done in the EU-projects SCOPE and Aurora

Water wash system installed at Tiller pilot



Pilot plant operating conditions

- Solvent: Used/degraded Cesar1 (3 mol/kg AMP+ 1.5 mol/kg Pz) solvent from a pilot in Niederaussen run by RWE.
- 160 m^3/h flue gas rate
- 5.3 kg/min liquid rate L/G=1.7 (mass basis)
- Flue gas CO_2 conc 10.5% (pure exhaust gas from propane burner)
- Capture rate ~90%
- Temp out DCC: 37.5 °C
- Pressure top desorber: 1.88 bar
- Typical SRD: 3.5 MJ/kg CO_2, (3.1 without heat loss)

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Test campaign at Tiller

- Initial test starting with pure water in the external washes
- Dynamic responses for changes in
  - WW temperature
  - Flue gas flow rates
  - Various capture rate
  - Number of water washes
  - Introduction of sulfuric acid aerosols using a TOPAS atomizer

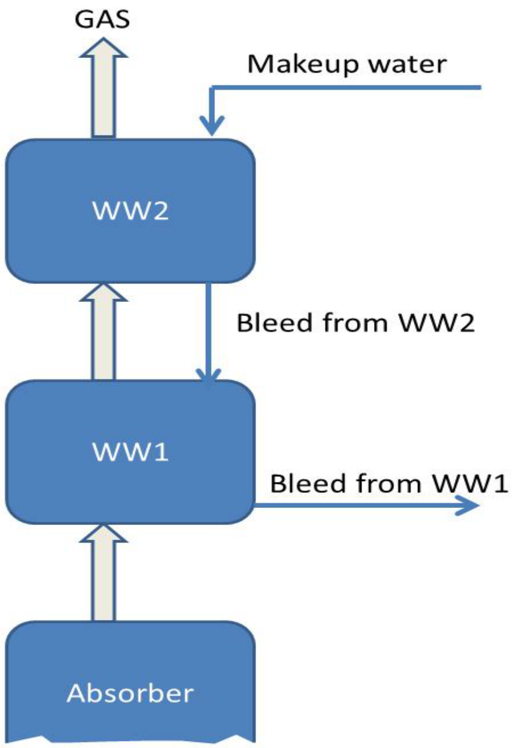
Model assumptions

$$P_{\mathrm{Am}} = \gamma_{\mathrm{Am}} P^{o}_{\mathrm{Am}} x_{\mathrm{Am\_free}}$$

- The water in each section is modelled as a CSTR (large recirculation of the liquid)
- The flue gas is modelled as a plug flow
- The gas composition out of the absorber and into the first section is based on the lean liquid composition into the absorber and the gas temperature leaving the absorber.
- The equilibrium model is based on the NRTL model made by NTNU. The model has included measurements from diluted systems.
- The gas leaving a WW section has a constant approach to equilibrium

$$P_{Am} = f_s \gamma_{Am} P_{Am\_eq}$$

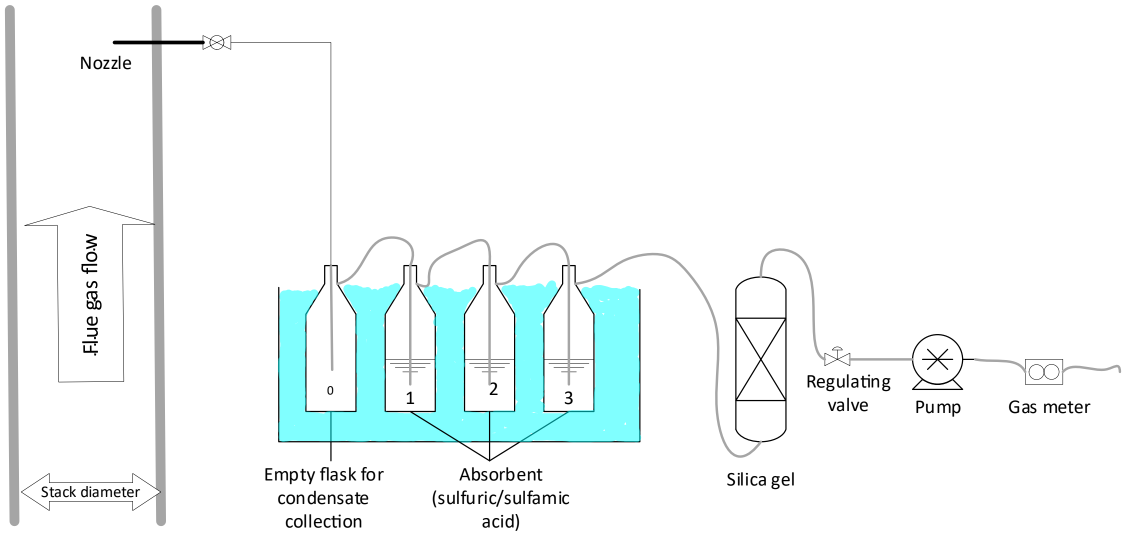
- The dynamic changes in liquid composition in are calculated from the dynamic mass balances in the section



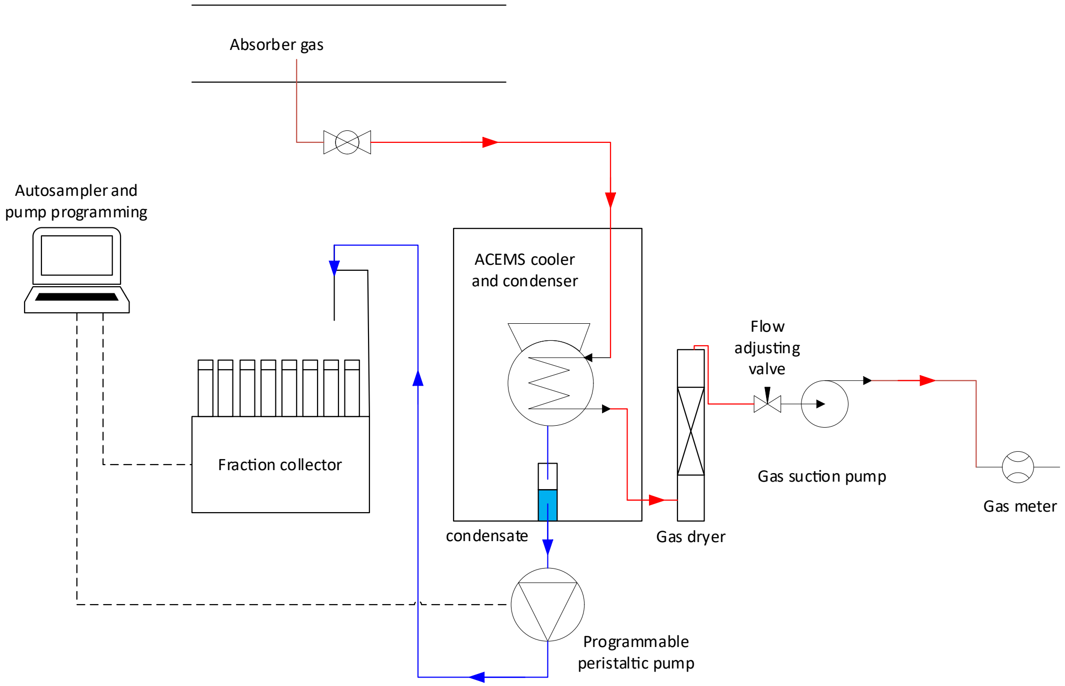
$$M_L \frac{dC_{Am\_ww3}}{dt} = G_{Am\_abs} - G_{Am\_ww3} + L_{ww4} C_{Am\_ww4} - L_{ww3} C_{Am\_ww3}$$

Analysing the gas composition from the plant (in addition to FTIR)

Manual sampling

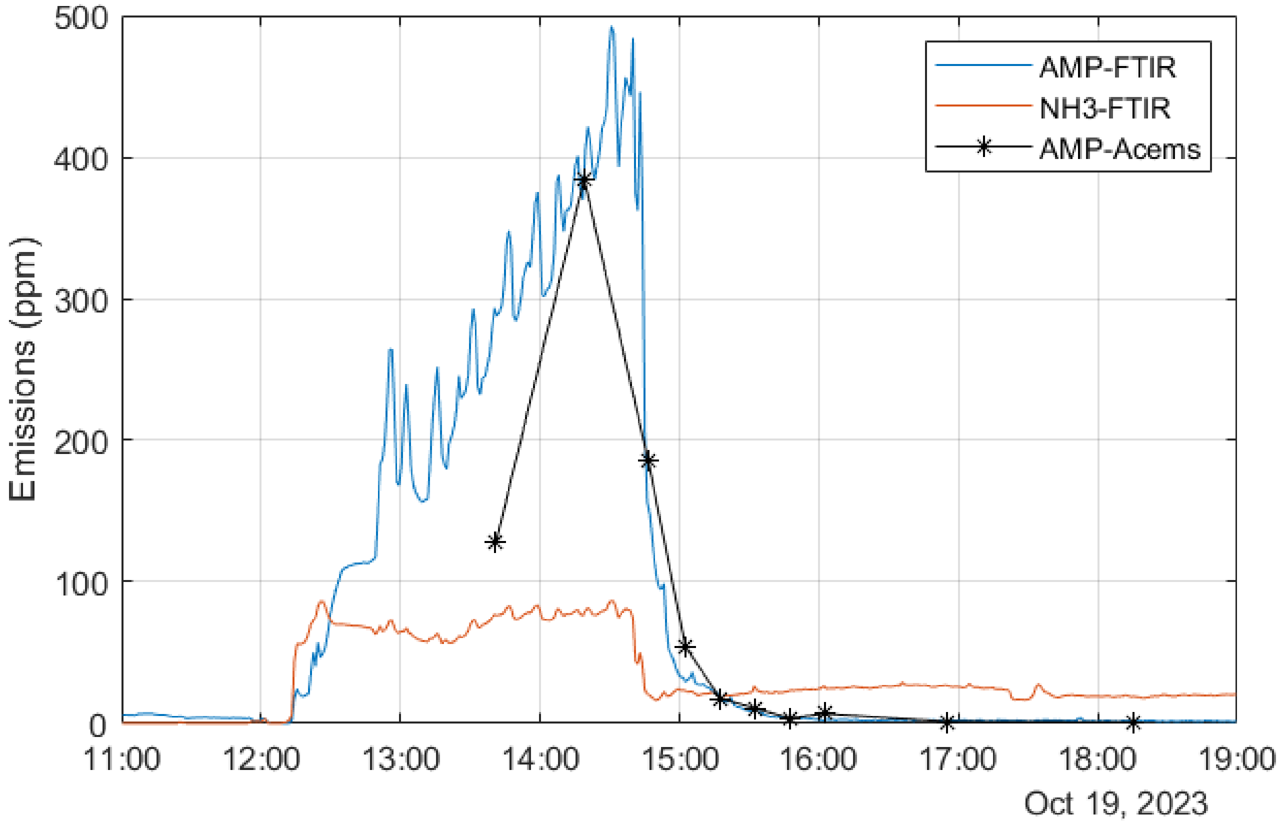


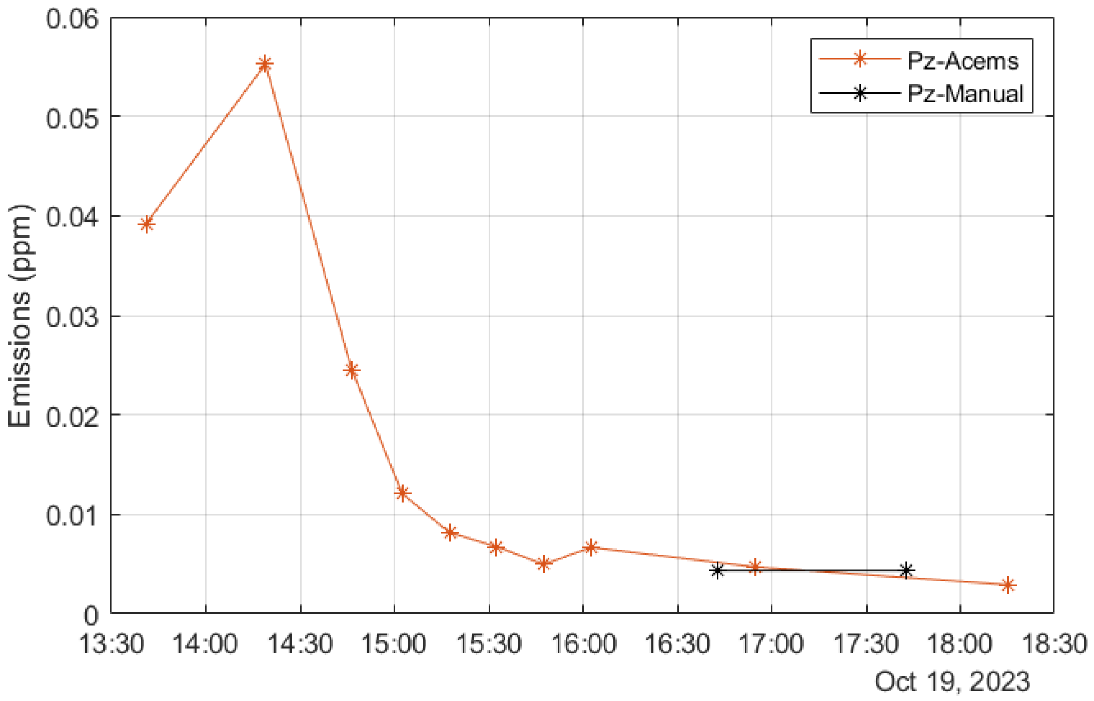
ACEMS automatic sampling



Starting conditions

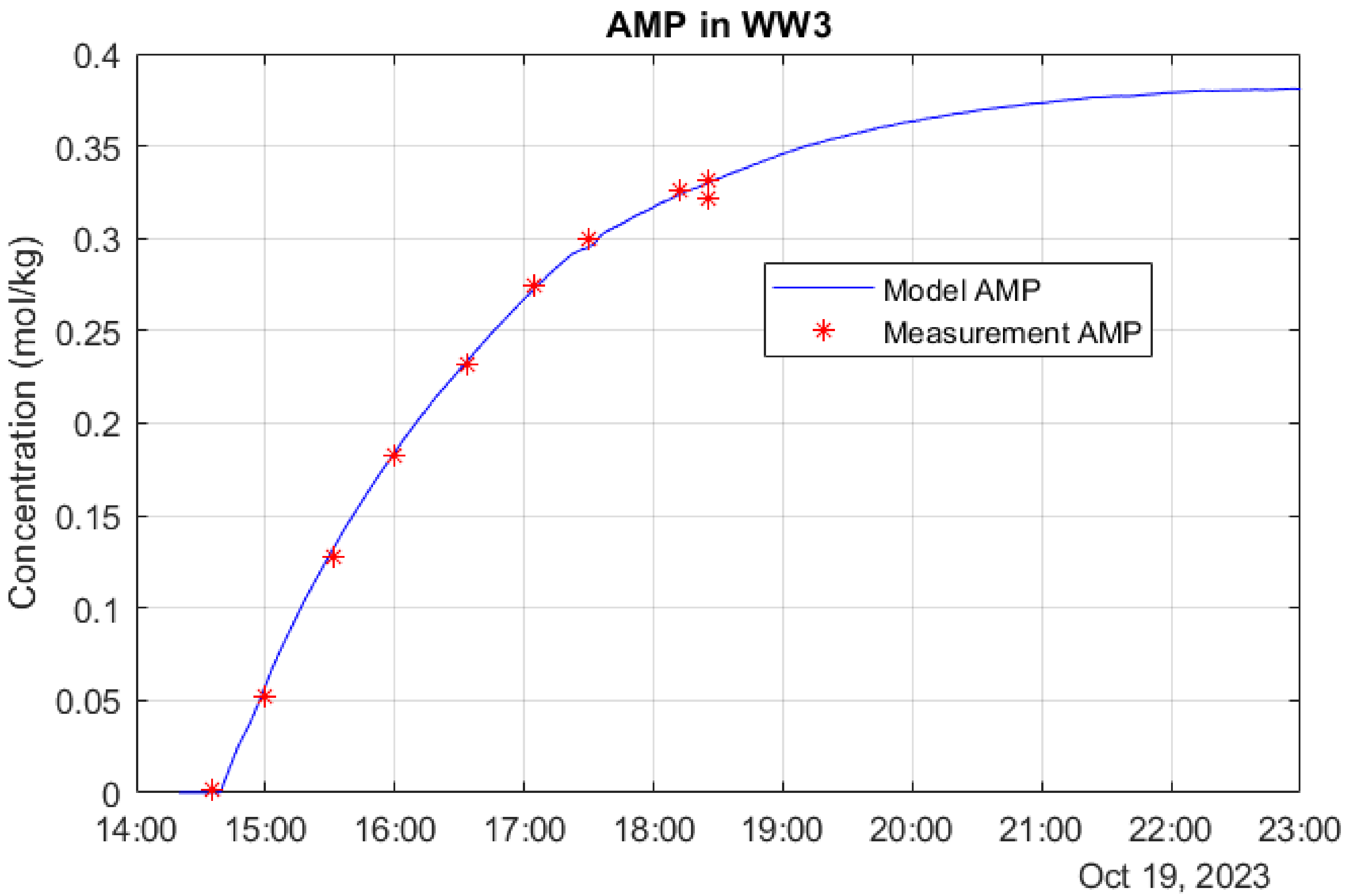
- The two external washes was filled with pure water and the circulation pumps ton
- The process was run for 2 hours without using any washes
- At 14:40 the gas from the absorber were sent to the two external water washes





Accumulation of AMP in WW3

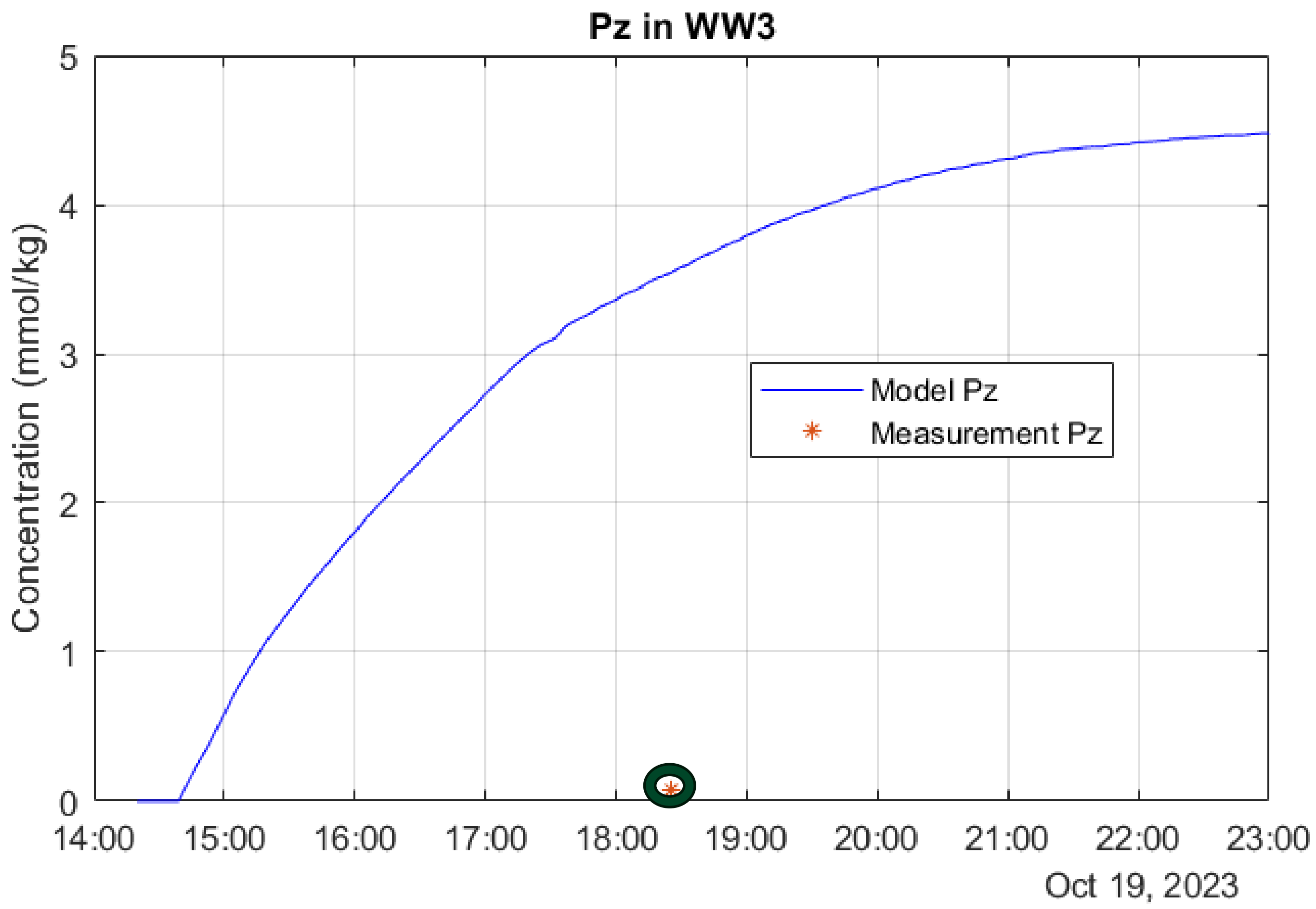
- The two amine components (and other degradation products) starts to accumulate in the water due to the imbalance in the mass balance.
- The model is compared with the results analysed liquid samples



Steady state after 7.2 hours

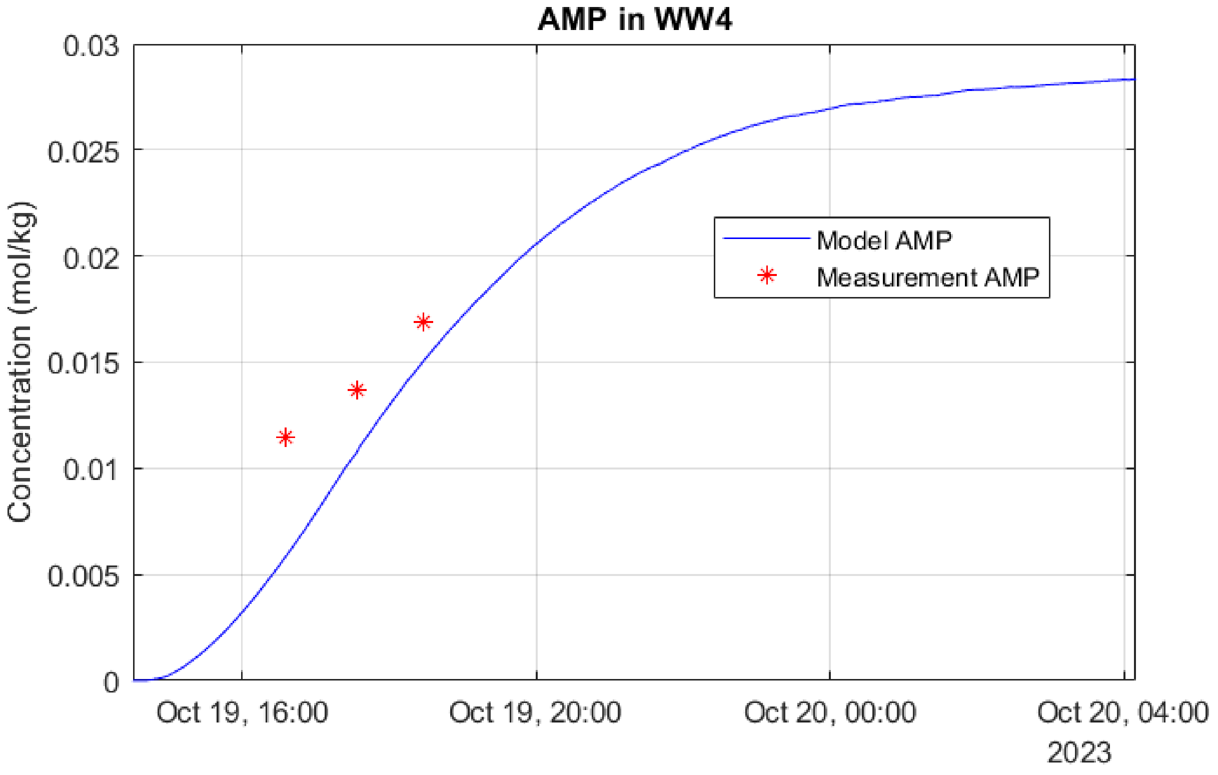
Accumulation of Pz in WW3

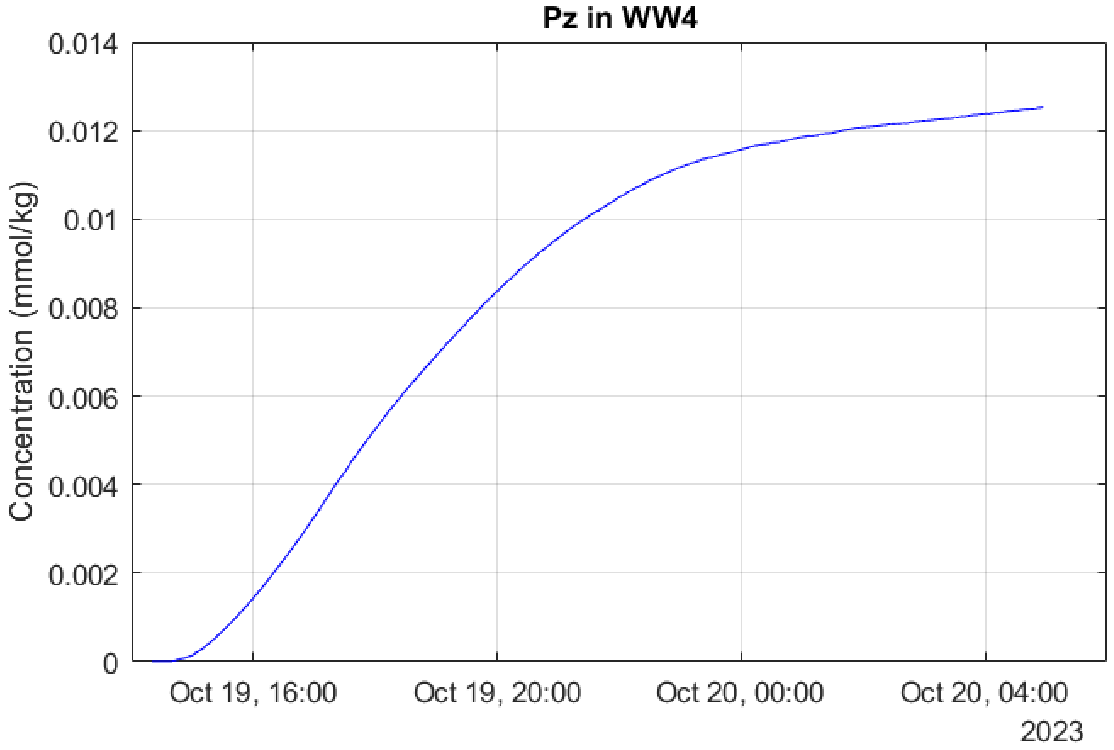
- For the Piperazine the difference was substantial. Note that the concentration of piperazine was analysed to be only 0.08 **mmol.**



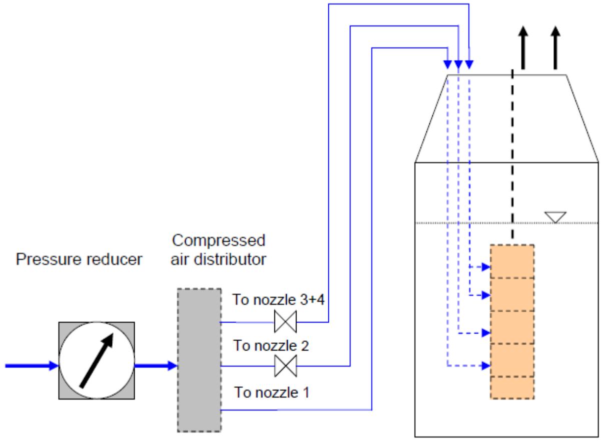
AMP and Piperazine in WW4

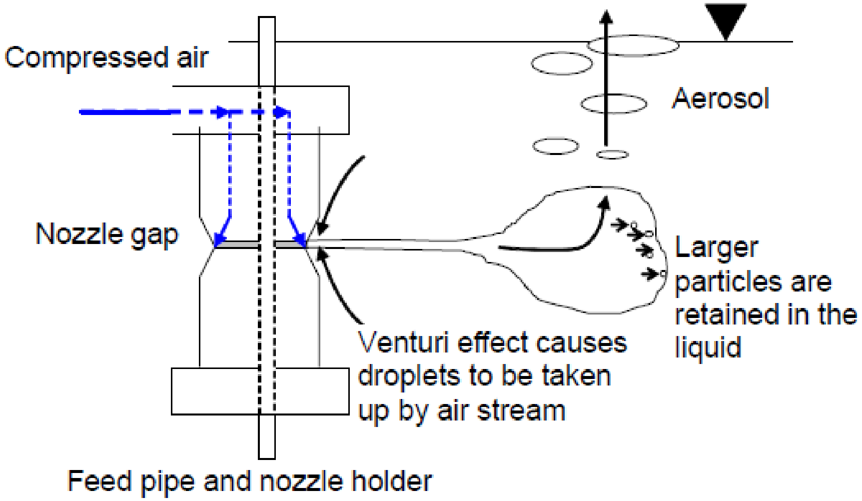
- For the AMP there are some minor deviation from the measurements
- The responses are much slower in WW4 than in WW3. Steady state reached after 14 hours





Introducing aerosols with TOPAS Atomizer





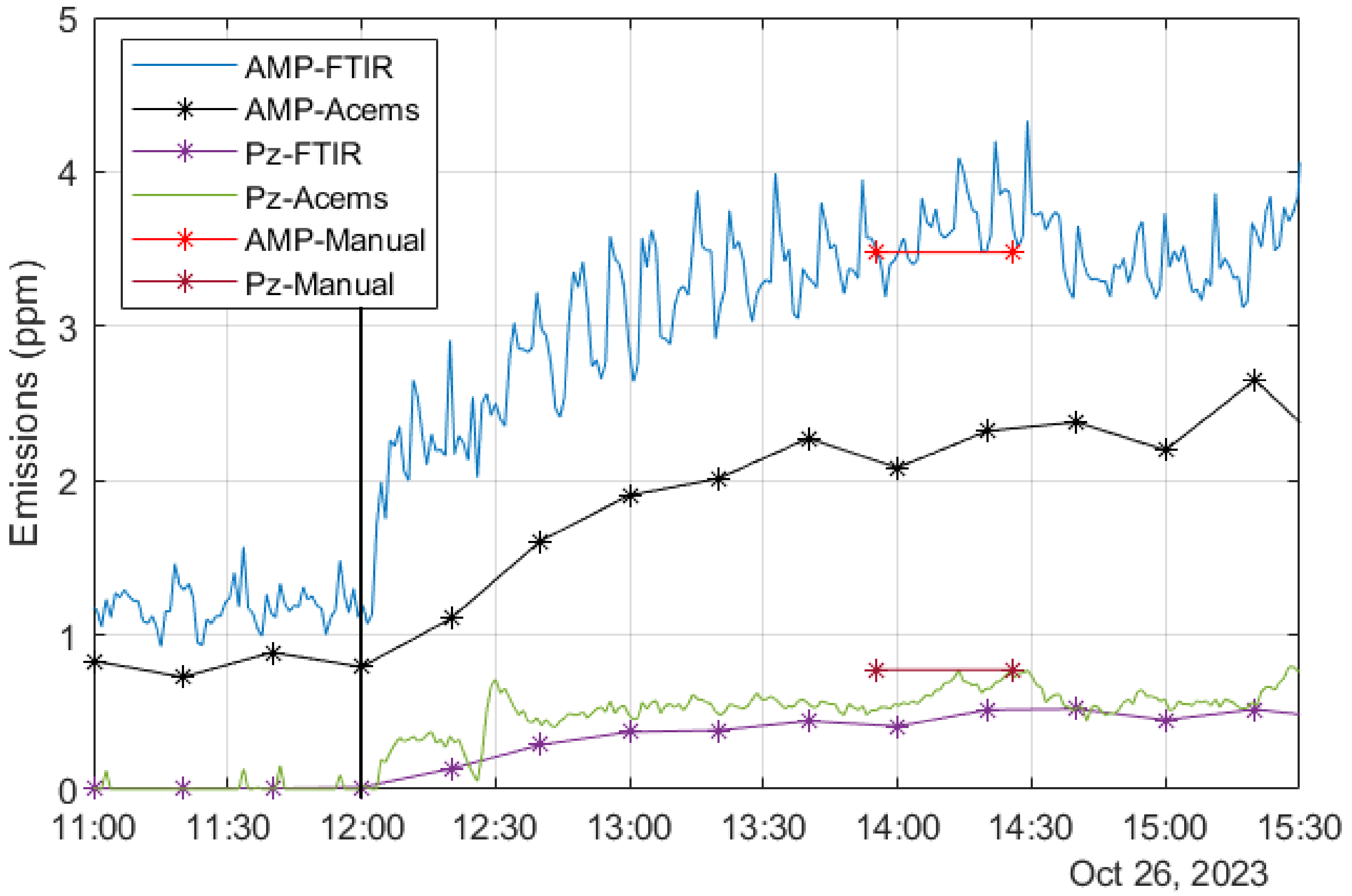
- Aqueous solution of H_2SO_4
  - (0.1, 0.2 or 0.4 wt%)
- Air Pressure (0.9 – 2.4 bar)
- Number of nozzles (1 – 4)

Higher concentration -> lager particles

Higher pressure -> more and smaller particles

More nosseles -> more particles

Aerosols was introduced at 12:00



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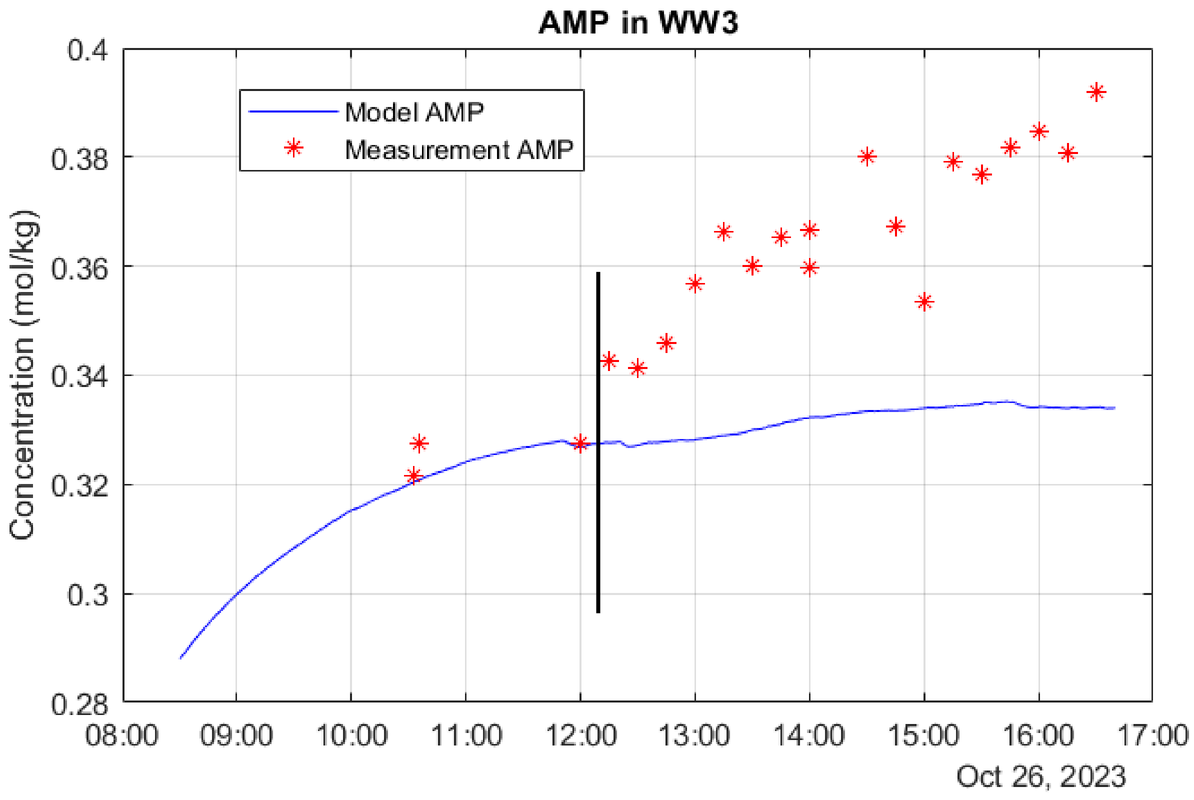

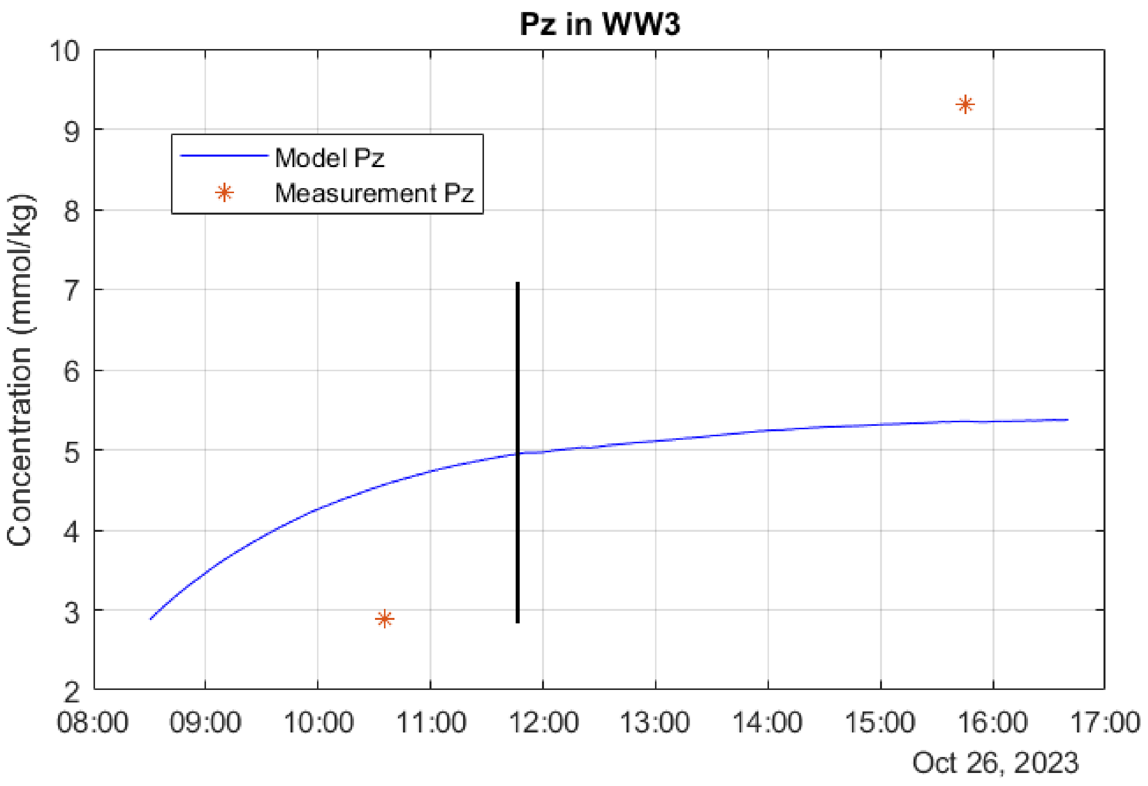

Summary

- The water wash model was in excellent accordance with the measurements for AMP in WW3.
- In WW4 there were some minor deviations.
- For Piperazine the contribution is almost zero and the model overestimated the concentrations substantially.
- More accurate equilibrium data and models should be developed for very diluted water wash system.
- The aerosols increased the emissions of both AMP and Piperazine.
- The concentrations in the washing waters also increases (transport from aerosols to the water)
- Since the model only includes vapour-based emissions, it can be used to distinguish between contributions from vapour-based and aerosols emissions.

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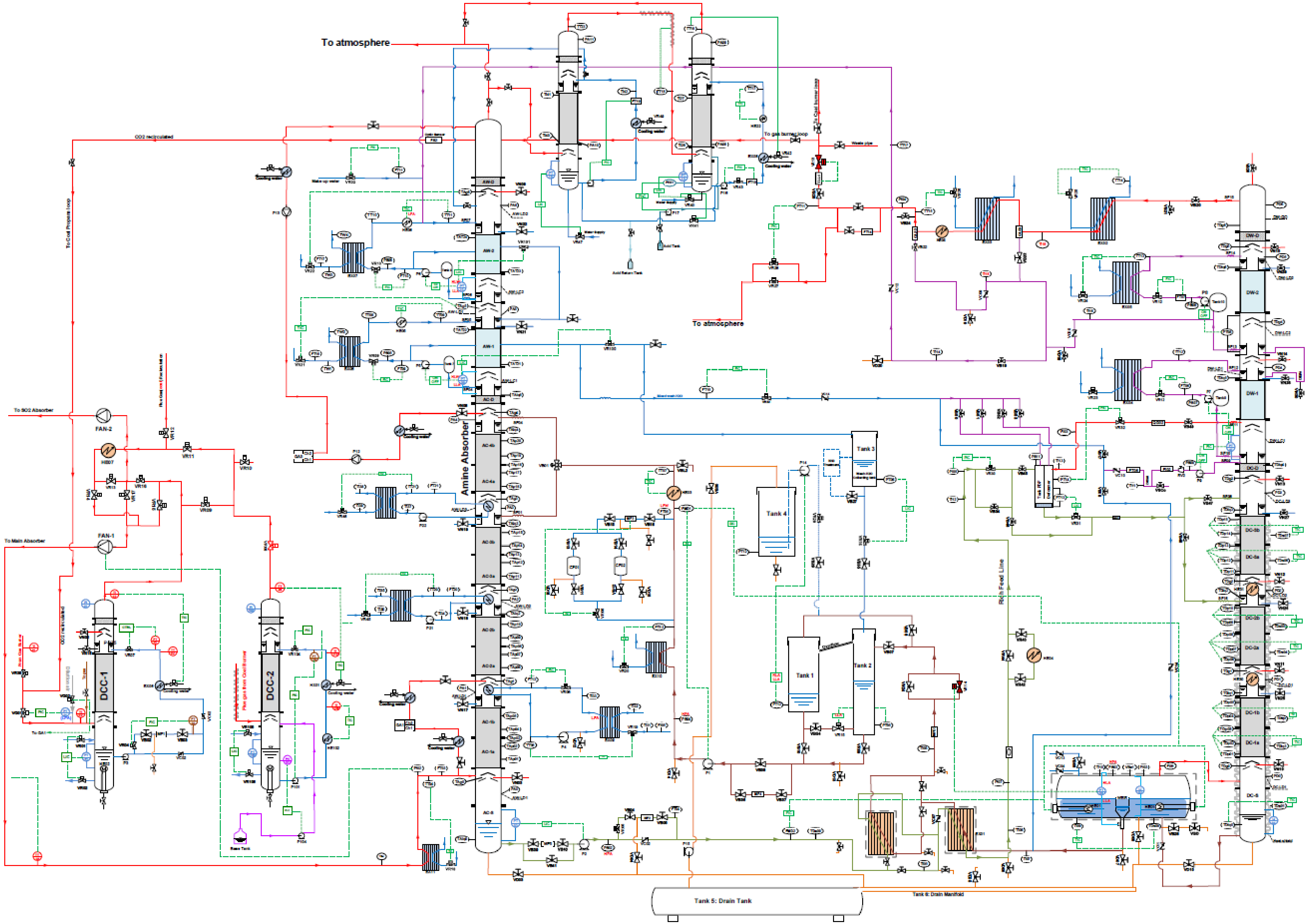
Thank you



To atmosphere
To atmosphere
CO2 recirculated
To Coal Propane loop
To gas burner loop
Cooling water
Amine Absorber
To SO2 Absorber
To Main Absorber
FAN-1
FAN-2
DCC-1
DCC-2
Tank 1
Tank 2
Tank 3
Tank 4
Rich Feed Line
Tank 5: Drain Tank